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EDUCATION POLICY | REVIEW ARTICLE

A systematic review of factors linked to poor academic performance of disadvantaged students in science and maths in schools

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Abstract: Socio-economic hardships put children in an underprivileged position. This systematic review was conducted to identify factors linked to underachievement of disadvantaged pupils in school science and maths. What could be done as evidence-based practice to make the lives of these young people better? The protocol from preferred reporting items for systematic reviews and meta-analyses (PRISMA) was followed. Major electronic educational databases were searched. Papers meeting pre-defined selection criteria were identified. Studies included were mainly large-scale evaluations with a clearly defined comparator group and robust research design. All studies used a measure of disadvantage such as lower SES, language barrier, ethnic minority or temporary immigrant status and an outcome measure like attainment in standardised national tests. A majority of papers capable of answering the research question were correlational studies. The review reports findings from 771 studies published from 2005 to 2014 in English language. Thirty-four studies were synthesised. Results suggest major factors linking deprivation to underachievement can be thematically categorised into a lack of positive environment and support. Recommendations from the research reports are discussed.

Subjects: Behavioral Sciences; Education; International & Comparative Education; Social Sciences

Keywords: underachievement; disadvantage; education; science; maths; attainment; school

ABOUT THE AUTHOR

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PUBLIC INTEREST STATEMENT

Successive governments across several countries have emphasised the importance of increasing and widening participation in science, technology, engineering and mathematics (STEM) subjects and careers. This is because STEM skills are considered valuable. It is certainly unfair if children are held back from achieving what they could due to circumstances beyond their control such as gender, ethnicity, poverty or neighbourhood. One of the first steps to help children from deprived backgrounds is to understand what reasons are cited in evidence-based research reports to be linked to their poor educational attainment. This systematic review summarises all those factors from robust studies and the recommendations made by them.

1. Introduction

> Educational disadvantage, starts in the womb – free maternal and child health care are an education imperative. (Education for All, Global Monitoring Report, 2010)

Attainment is important. Several factors can however potentially limit a child's academic achievement. Contextual indicators continue to be the determining parameters for educational attainment, learning trajectories and careers. Adversities in education are faced by ethnic minorities, refugee/asylum seekers, immigrants, young people who have spent time in care and poorer pupils (OECD, 2016; Strand, 2014). Eligibility for free school meals (FSM)/reduced price lunches, family income below a certain threshold, residence in a potentially deprived area or low progression neighbourhoods identified by indices of multiple deprivation are all indicators of a lower socio-economic status (SES) and efforts for widening participation agenda are targeted by government in the United Kingdom and elsewhere. These policies are in place to remediate the unfair underrepresentation and underachievement of children and young people in learning trajectories. Free compulsory education to a certain age is one of the efforts under this policy in developed countries.

1.1. Rationale for conducting the systematic review

Disadvantaged pupils do not perform as well academically as their elite peers (Reardon, 2011; Steele, 2010). Evidence comes from a study exploring the effect of poverty on achievement of urban African-American students successfully completing high school. Welch (2014) shows cumulative 10th-grade GPA was strongly negatively correlated with student poverty level. As the poverty of the student increased, the cumulative GPA decreased. An extrapolation of this research finding could mean beyond compulsory education poorer scores render deprived pupils ineligible for several courses held in high esteem such as science, technology, engineering and mathematics (STEM). Evaluating large secondary government national data-sets Banerjee (2015, 2016) shows STEM educational interventions have not been able to raise pupil performances in standardised national tests nor widen participation in the UK.

This situation certainly needs remediation as (a) it is always desirable to have a range of people from different sections of the society studying and working in different fields for instance, having a diverse intake for STEM courses will lead to a more innovative and responsive STEM workforce (RAE, 2012), (b) for narrowing the socio-economic divide as people in STEM occupations earn almost 26% more than those working in other fields (Langdon, McKittrick, Beede, Khan, & Doms, 2011), (c) for issues of social justice—higher education has a responsibility to maintain fair access to all irrespective of SES, gender or race (HEFCE, 2014), (d) to enable students to harness on STEM skills even if opting out of a STEM career, (e) educational attainment appears to have a protective effect against accelerated cellular ageing (Adler et al., 2013), major depressive disorders (MDD) (Shi et al., 2014) and degenerative diseases particularly in disadvantaged groups.

The first step towards bringing about this change is to have a thorough understanding of the reasons linked to underachievement of disadvantaged pupils in science and maths education in schools as evidenced in research literature. The second step is to understand how some pupils or schools despite operating in most adverse conditions refused to become statistical failures and whether the lessons learnt from them can be translated to society at large. The third step is to explore whether recommendations have been made based on experimental success, which could be picked up for policy and practice.

This systematic review was conducted as a part of a national evaluation research project based in the UK. The main idea was to gain a thorough understanding of factors linked to underachievement of children in school science and maths. Thus the primary aim was to enrich the knowledge base with all such research reports relevant to the UK conducted in similar developed countries. Thus it is likely the findings summarised at the end may appear to be US/UK centric. However, often there were studies conducted in other countries whose social conditions were not similar to UK but the

deprivation measures directly linked to what the research project was investigating such reports were also included. Further, attempts were made to include all papers at any stage of school or pre-school education which were likely to be able to offer an explanation for young people's educational outcomes in science and maths standardised national tests.

1.2. Objectives

A child born in a family qualifying for several deprivation measures is extremely vulnerable and is bound to face challenges all through life starting early-on. This translates into compromised leaning trajectories, reduced employment opportunities and lower income, setting thereby a trend of poverty/disadvantage. It is essential to break this chain for uplifting deprived sections of the society. This systematic review was conducted to understand the various factors which provide an explanation for the underachievement of disadvantaged pupils in school science and maths. The term disadvantage here refers to the absence of certain conditions as in other more privileged sub-groups who face lesser hardships in life and encounter fewer barriers during their learning trajectories.

1.3. Research questions

The review aimed to systematically locate, quality appraise and synthesise academic literature suggesting potential factors for poor academic performance of underprivileged pupils in science and maths in school. Thus, problem specification considered relevance to the UK population, age group (pre-school to school), disadvantage measures, educational/behavioural outcome variable. The main research question being addressed is:

> Which factors are associated with disadvantaged pupils' lower attainment levels in science and maths in schools?

While focusing on the above research question the review also tried to collect evidence on schools/pupils qualifying for several measures of disadvantage who performed extremely well for instance high poverty, high achieving schools. Some programmes from robust studies shortlisted for the above research question were very effective in raising academic achievement of disadvantaged pupils. These were identified and categorised as effective recommendations discussed later.

2. Methods

This review followed the PRISMA protocol (Moher, Liberati, Tetzlaff, & Altman, 2009). After formulating the research question, systematic and explicit methods were used to identify, select and critically evaluate relevant research reports from major educational databases. The framework for all stages was pre-planned (Banerjee, 2015). Electronic searches began with major educational databases ERIC, ProQuest, PsycINFO and Social Science Citation Index. English language peer-reviewed journal articles, reports, government and official publications, dissertations and theses, conference papers and proceedings were all included. This was followed up with hand searching of relevant journals. Research papers from experts in the field were also included in the review. Studies relevant to the research question using a robust research design and clear measures of deprivation such as FSM eligibility/reduced price lunches, geographical location of residence in a disadvantaged area, speakers of English as additional language, ethnic minority status and low parental income were included. All studies used an outcome academic measure of achievement in science and/or maths such as student performance in standardised national-level tests, state-level exams or school performances. English language papers published between 1.1.2005 and 31.12.2014 were shortlisted for the review.

A balance between sensitivity and specificity in searching literature was aimed at by using thesaurus terms of keywords, truncation and using the "NOT stem cell" term for excluding all studies that were being returned for stem cell research in the preliminary searches. Explicit inclusion and exclusion criteria were developed specifying which studies were to be included in the review, for instance, criteria in terms of research design, population, language and timeline. All relevant published and unpublished literature was identified. Each study or report was quality assessed individually by three

researchers, on parameters such as relevance to research question, robustness of evaluation, research design, sample size, comparator and trust worthiness of the study. Findings from individual reports were synthesised using the grounded theory approach (Glaser & Strauss, 1967). These were then interpreted in a balanced and impartial summary with due consideration of any flaws in the evidence.

This systematic review is thus more reliable than a narrative review as it provides minimisation of bias for information on the research question. However, statistical methods (meta-analysis) were not used to analyse and summarise the results of shortlisted studies. This is because the studies addressed a range of disadvantage measures hence it would not have been fair to cluster them together. To eliminate bias the data were screened by two researchers and quality assessment done by three researchers. Due to space constraint this paper discusses the results followed by implications for policy and practice. For a more detailed discussion of the methods and the review protocol, please see Banerjee (2016).

3. Candidate modifiable factors associated with underachievement of disadvantaged pupils

The main themes which emerged from the synthesis of papers in this review were contextually – individual, family, neighbourhood and school-level indicators. Yet as discussed in the OECD report (2016) the major deprivation measures such as lower socio-economic status, ethnic minority status, speaking English as an additional language, immigrant status all have certain common features which lead to (a) lack of positive attitudes towards school and learning and (b) less supportive environment. This paper discusses the agents which link all of these deprivation measures and underachievement in STEM subjects. These are discussed below.

3.1. Lack of positive attitudes towards school and learning

Associations between negative emotionality and cognitive performance of children living in poverty have been examined by some research. The Early Head Start is a federally funded (US) early childhood development program aimed at low-income families. Early head start (EHS) research and evaluation project was a prospective study of 3,001 children and families living in poverty. Ayoub et al. (2009) found 1–3-year-old children who had higher levels of negative emotionality evidenced more rapid rates of decline of cognitive skill scores. The protective effect of EHS on such children's cognitive skill performance however was quite evident. Children who were enrolled in EHS had higher cognitive skill scores at three years of age than their peers who were not in EHS.

3.1.1. Neighbourhood effects

Neighbourhood economic hardship was identified as an important predictor of children's lower maths attainment (N = 1006, US) by Hanson et al. (2011). Possible reasons cited were lack of role models in the low academic progression areas where they lived. Equally importantly because teaching work force and learning resources available in schools in high poverty areas are not as rigorous as those in posh/urban schools. Similarly, high risk behaviours such as drug abuse—marijuana, stealing, participating in group against group fight has been linked to lower SES pupils residing in deprived localities. One of the arguments for such behaviour could be to try to fit among other children in neighbourhood. It is easier to fit into neighbourhood community by acting like the majority rather than being branded as too idealistic and being a trend setter. A longitudinal RCT conducted in Chicago shows significant benefits of value-added education in preventing the link between SES and these high risk behaviours (Tobler, Komro, Dabroski, Aveyard, & Markham, 2011).

Experiencing and exhibiting aggression and violence is strongly associated with lower socio-economic status. These undesirable behavioural patterns are highly and disproportionately prevalent among school-aged urban minority youth. Basch (2011) highlights causal pathways through which aggression and violence slow down learning include affected cognition, lack of school connectedness and absenteeism. Disruptive classroom behaviour is a well-recognised and significant barrier to teaching and learning.

3.1.2. Familial factors – lack of parental academic involvement, authoritative parenting, lower maternal education and family background

An important role is played in the lives of children by their families – academic or otherwise. However, families living in high poverty, high unemployment and low-education neighbourhoods are known to employ fewer education-oriented practices with their children. Research suggests the effect of such parental practices on children's maths achievement is extremely encouraging. Parental academic involvement has been shown to have a strong effect on children living in disadvantaged localities (Greenman, Bodovski, & Reed, 2011) through a large-scale study involving a nationally representative database of American elementary school students.

Parental interest in their offspring's studies may in fact have shielding effects on academic achievement brought about by deprivation. An explanation offered for this is perhaps it camouflages the effect of a range of risk involving factors—low socio-economic position, psychological and physiological stress, negative emotions. In particular, parental interest in their children's studies during the last year of compulsory education was found to better predict adult allostatic load, which is merely the physiological outcome of chronic exposure to stress or negative emotions. Parental academic involvement also increased life course academic and occupational achievement in their children. Westerlund, Gustafsson, Theorell, Janlert, and Hammarstrom (2013) provides evidence that parental involvement is a more definite predictor as opposed to parent's social class or availability of practical academic support (N = 365 women, 352 men).

Children whose mothers have less than a high school education have lower cognitive skill scores at three years of age (Ayoub et al., 2009; Hanson et al., 2011). Similarly, teen mothers and mothers who are illiterate or unemployed are more likely to raise academically underachieving children as compared to those who have a primary or tertiary level of education despite belonging to the same SES (N = 3001, national datasets USA).

Authoritative parenting has been shown to be a significant predictor of self-efficacy and resilience and positively correlates with academic achievement. A justification available for this is perhaps by acting as influential role models parents add a shield against deprivation by mitigating risk factors which reduces the achievement gap (Speight, 2010). A direct influence of parental support on at-risk status, academic performance, hopelessness, explanatory style and depression has also been established by a study of non-clinical sample of 213 African-American students by Bryant (2007).

Using PISA data from more than 40 participating countries, Nonoyama (2005) in a cross-national study tried to understand the effect of family background on student achievement. The study concluded family SES and background effects had a larger bearing on student achievement than SES alone or school effects across countries. Just as parental support and involvement sometimes the conditions under which children thrive affects their educational outcomes. Pinder (2010) using a causal comparative design administered survey questionnaires on 87 high school students in the United states to explore the impact of family background on science achievement. He concluded arrival status of immigrants impacts their achievement. First generation voluntary immigrants perform much better academically compared to those individuals whose ancestors were forced to migrate.

Similarly, children of incarcerated parents were found to be 3.8 times more likely to be raised by a caregiver who had less than a high school education. Such children showed a trend in lower test scores compared to their peers in single parent households and of similar socio-economic status (Neal, 2010) experiencing similar negative emotionality. Parental incarceration as the author suggests puts a child at risk of lower educational attainment both during and after parent's release – perhaps one of the major reasons being the failure to reintegrate in the society.

3.1.3. Futility culture – temporary immigrant status

Apart from individual factors, children of temporary immigrants/guest workers have an additional layer of disadvantage to deal with. Multilevel analyses of data based on a survey of 2,845 pupils

(aged between 10 and 12 years) in 68 Flemish primary schools (Agirdag, Van Houtte, & Van Avermaet, 2012) revealed that a higher proportion of immigrant and working-class pupils in a school is associated with lower levels of math achievement in both immigrant and native Belgian pupils. The study found that the ethnic composition of the school no longer had a significant effect on pupils' achievement, while the SES composition did.

A possible explanation could be immigrant status demands a lot of social and cultural adjustments. If the transition is temporary most parents and children look forward to going back to their native education system and perhaps do not value current education as much as they would normally have. Equally importantly immigrants are faced by a lot of challenges some of which are linked to basic survival. Child's education then perhaps takes a lesser priority within the family. One of the most important conclusions drawn from the study indicated that the remaining impact of SES composition can be explained by pupils' sense of futility and schools' futility culture. Pásztor (2008) using PISA data show institutional factors can impact on school-related integration and help alleviate some of the problems.

Young people from disadvantaged backgrounds thus often face multiple negative situations in their ambience which takes them away from education. Their circumstances are worsened if they are faced with unsupportive environments in school and society.

3.2. Less supportive schools and teachers

3.2.1. Teachers' expectation

Discipline gaps, achievement gaps and attendance (Alsace, 2009; Graber, 2010) are all very strongly correlated. An analysis of 10th-grade sample of US Educational Longitudinal Study shows student perceptions of teachers and teacher's attitudes can predict academic performance and discipline. Using SES as a measure of disadvantage the study provides evidence that students' relationship with teachers, perception of teacher sensitivity and the reasons for attendance are the strongest predictors of scholastic achievements. Students in the lowest SES quartile very often did not attend school because of their teacher's expectation of success and for the fear of humiliation in class (Whitehead, 2007).

Strambler and Weinstein (2010) using a sample of 111 students from California showed student's higher perception of negative teacher feedback predicts more devaluing of academics and greater perceived teacher care at classroom level predicts less devaluing. A lower regard for academics consistently predicts poorer maths test scores. Positive teacher expectations, support and motivation have progressive effects on students regardless of their risk status and particularly for lower income students (Gregory & Huang, 2013; Sorhagen, 2013).

3.2.2. School contextual factors – organisation model, size and climate

Transition age pupils are quite divided in their perceptions – to some stepping up to the secondary school is an opportunity and to others a challenge. Vaz, Parsons, Falkmer, Passmore, and Falkmer (2014) concluded from a prospective longitudinal study (USA) the primary school organisation model significantly influences post-transition academic competence (AC) in secondary schools. Students attending independent and mid-range sized primary schools had the highest concurrent AC; students from kindergarten-year7 schools report the lowest scores while attending a school with the kindergarten-year 12 with middle school structure was associated with a reduction in AC scores across the transition. The study however concluded that the contribution of social contextual factors was relatively minor as individual level background factors account for majority of variability in post-transition AC.

Similarly, lower SES pupils have been shown to have significantly lower dropout rates in small-sized schools as opposed to large-sized schools (Alimohamed, 2011). School climate constructs have been shown to be related to student achievement (Smith, 2008) by some research. Johnson-Brown

(2014) using the population of all 11th-grade students in West Virginia shows school size, rural location affect test scores. Children from larger schools perform better. The more rural a school the poorer the performance compared to an urban and sub-urban school.

3.2.3. Perceived discrimination

Minority adolescents experience situations in their everyday lives that they sometimes interpret as unfair. The implications of this perception on the educational attainment of these youngsters are expected to be negative but are relatively less researched. Borsato (2008) examined perceptions of discrimination among early adolescents of Asian-American and Latino descent. 409 students (96 Asian-Americans, 126 Latinos and 187 Whites) attending grades 7th and 8th at a public junior-high school located in Northern California participated in this cross-sectional study. Students were asked to complete an anonymous questionnaire which asked questions about having ever experienced stressful events that they interpreted as connected to their race/ethnicity, demographic background. Details of measures of racial/ethnic identity, depressive symptomatology, problem behaviours (drug use, delinquency and physical aggression), academic motivation and achievement of these pupils were collected.

Despite their young age, minority participants reported having already experienced one or more situations that they perceived as racial/ethnic discrimination. In addition, perceived discrimination by adults was highest for Latino adolescents, while perceived discrimination by peers was high for Asian-Americans. Survey data analysis suggested perceived discrimination is a risk factor for psychosocial and academic outcomes. Peer discrimination significantly predicted depression, delinquency and negatively predicted motivation while adult discrimination predicted physical aggression, drug use and negatively predicted student grades. Research findings support the possible mediating role of adult discrimination relative to the academic achievement gap between Whites and Latinos.

A positive connection to one's racial/ethnic group termed – "high private regard" by the author, emerged as a resilience factor for depressive symptoms and academic motivation. Similarly, "public regard"—the extent to which individuals felt that others view their racial/ethnic group positively or negatively was significantly associated with school importance. The perception that one's group is valued in society predicts a stronger belief that school is important. Organisational citizenship behaviours and measures of student achievement in Biology also showed a significant positive correlation (Tindle, 2013).

3.2.4. Oppositional culture

Analysing data from the US Education Longitudinal Study, a nationally representative panel survey of high school sophomores and seniors Wildhagen (2009) showed schools with high levels of Black–White inequality—in terms of number of pupils from each group; discourage Black students with good grades from taking as many advanced placement courses as they would in schools with less inequality.

Greene (2009) using data from the National Educational Longitudinal Study showed racial-ethnic minority students are disproportionately placed into lower level academic courses and programs including vocational education. The young learner's response is lower school engagement as opposed to their white peers. This perhaps is one of the factors leading to unrealised academic potential among black students.

3.3. Other factors linked to disadvantage

Evaluating fifth-grade children from low-income urban schools using clinical neuropsychological tests and behavioural questionnaires Waber, Gerber, Turcios, Wagner, and Forbes (2006) wanted to find out if executive functions are selectively diminished in children from poor urban environments and does integrity of executive functions predict test scores. Neuropsychological variables (particularly executive functions) accounted for 30% variance in mathematics scores among participants. Waber et al. (2006)reports these children were not moderated in terms of their basic information processing or their psychosocial adjustment. However, despite their competence on

neuropsychological measures—which are deemed indicative of risk for learning problems, such as working memory and processing speed, these children obtained fourth-grade scores on state mandated standards-based testing. They do, however, exhibit relatively selective impairment of metacognitive skills and behavioural regulation. This is demonstrated in everyday classroom behaviour, which appears to be strongly associated with achievement test performance.

One of the main reasons affecting these neuropsychological changes is malnourishment among children. Food insecurity or a lack of knowledge of health benefits from food due to lower level of parental education or minimal resources hampers physical growth, health and intellectual development of children. Belachew et al. (2011) shows the extent to which food insecurity affects school attendance and educational attainment. The study used a stratified random sample to select participants. Data were analysed from 2009 adolescents in the age group of 13–17 years from two consecutive surveys of a five-year longitudinal family study in Southwest Ethiopia. School absenteeism and the highest grade attained after 1 year of follow-up in food secure and insecure adolescents were compared using regression analyses. The analysis was adjusted for demographic factors, reported illness and workload. Multivariable logistic regression analyses showed that adolescent food insecurity, severe household food insecurity, illness during the past one month before the survey, the highest grade aspired to be completed by the adolescent and the number of days that the adolescent had to work per week were independent predictors of school absenteeism. Similarly adolescent food insecurity, severe household food insecurity, illness during the last month and rural residence were inversely associated with highest grade attained. Highest grade intended to be completed by the adolescent and residing in semi urban area were positively associated with the highest grade attained. The study concludes adolescent and household food insecurity is positively associated with school absenteeism and a lower educational attainment.

Administering school-based surveys (N = 1,195) Doku, Koivusilta, Raisamo, and Rimpelä (2013) explored the patterns in breakfast, fruit and vegetable consumption among 12–18-year-olds in Ghana. The study aimed to study any association between child's SES, dietary habits, health and educational attainment using logistic regression analyses. The main research findings are the probability of having a regular breakfast is higher in adolescents from more affluent backgrounds than in those from less affluent ones. Further compared to unemployed/illiterate mothers, those with primary or tertiary educational attainment are more likely to have frequent fruits/vegetables intake. Adolescents' academic performance in high school was positively associated with frequent fruit/vegetable intake. Some research also presents evidence on a negative correlation between poor nutrition, fast food consumption and test scores in the USA (Tobin, 2013). Though the study focuses on developed countries the research reports from Ghana, Ethiopia and USA confirm irrespective of the country where research was conducted nutrition affects educational outcomes.

Similarly, Malacova et al. (2008) using Australian population data-sets shows birth characteristics like optimal term birth, increased growth in head and length and being first born to mothers residing in most educationally deprived neighbourhoods were associated with higher numeracy scores, among disadvantaged children. Poor oral health, depression, asthma have all been linked to impoverished academic achievement of deprived pupils.

Children face racial and class discrimination, decreased self-esteem, poverty, outdated and/or limited curriculum resources, and less than acceptable facilities, as well as many other problems associated with inner-city life all of which can negatively impact their attitudes and aspirations. Rather than one single stumbling block more than one of these factors act together to hinder a child's scholastic progress. This is further supported by Bruner (2014) through an international comparison using TIMSS, 2011 8th-grade science data. The main aim of this study was to understand what factors hinder the achievement of low SES pupils using a six country sample. The research findings suggest student, teacher, classroom and school level factors lead to inequities in achievement. The results of this review support the findings of the TIMSS (2011) and OECD (2016) report.

4. What recommendations are available from literature for improvement?

Academic literature shows several factors could be used for levelling the playfield for those from disadvantaged backgrounds. All of these could possibly benefit all young people irrespective of their backgrounds. These could help raise their educational attainment for a better overall life. Lower levels of negative stress, high physical comfort and good health of pupils have been shown to have positive effects on teacher connectedness, school engagement and academic achievement. Negative emotions such as bullying, aggression and violence adversely affect these outcomes (Forrest, Bevans, Riley, Crespo, & Louis, 2013; *N* = 1,479, US). Similarly, positive self-perceptions about academic abilities (Burrichter, 2006), high educational aspirations, empathic understanding, an internal locus of control and hope for the future have been deemed as protective factors contributing to the academic resilience of students living in poverty (Gizir & Aydin, 2009). Robust studies screened in the systematic review showed the factors below could go a long way in improving educational outcomes for young people.

4.1. Self-concept, equality and academic achievement

Academic self-concept has been shown to be correlated to scholastic achievement. People who matter most to a child—such as teachers, parents and peer group play a very important role. Gregory and Huang (2013) shows positive expectations of students, parents and maths teachers in 10th-grade students had positive impact on academic performance irrespective of student's risk status (*N* = 15,000). Significant relationships in a child's life could raise performance in school and reduce dropout rates. Structure imposed by teacher in the classroom, perception of degree of trust and communication with mother, pupil's perception of what others think about them could make a difference to academic achievement (Burrichter, 2006) of disadvantaged pupils.

Wildhagen (2009) suggests from analysis of large-scale US national datasets, disengagement from school accounts for relatively higher unrealised potential among blacks than whites. Similarly, lack of school values has been shown to leave disadvantaged children further behind (Blake, 2012). Using data from the Educational Longitudinal Study, Boccanfuso (2009) suggests a link between presence of school membership within disadvantaged students with high levels of academic performance and effort. Promoting equality in academic opportunities in schools and sustaining high levels of engagement throughout school could be a step towards raising pupil's self-concept and raising attainment.

4.2. Motivation

Absence of role models and mentors from social environment among young people and their families in disadvantaged areas are often thought to explain the poor education levels and jobs (Bricheno & Thornton, 2007; *N* = 197 boys, 182 girls) of disadvantaged pupils. However, a clear causal relationship between attitudes, aspirations and children's educational outcomes is not established in literature in the absence of robust evaluations (Gorard, See, & Davies, 2012). However, Zelei (2005), examined student survey responses related to motivational conditions between and within race, gender, high school academic course level. The study concluded in order to reduce disparities teachers and school administrators need to understand the differences and similarities which exist between pupil motivational conditions and establish appropriate academic expectations for students by improving instructional strategies.

In perhaps what could be termed as an assessment of efforts to motivate, Anderson and Mezuk (2012) investigated the relationship between academic achievement and participating in a high school debate program on college-readiness in the Chicago Public School district over a 10-year period. Study participants were at-risk school students—identified using an index including prior attainment in grade 8, poverty status, and enrolment in special education. Regression analyses were used to assess the association between debate participation and graduation and science performance. Overall, debaters were 3.1 times more likely to graduate from high school than non-debaters, and more likely to reach the college-readiness benchmarks on the English, Reading and Science. Debate intensity was positively related to higher scores. Anderson shows debate participation is

associated with improved academic performance for at-risk adolescents. A possible explanation could be deciphered by the science involved during the preparation the child makes for preparing the text for the debate, Equally importantly perhaps the cumulative effects of the positive thought process and the confidence which is instilled while standing up to speak.

4.3. Teacher effect

Teacher's intentional or unintentional classroom actions, expectations (Gregory & Huang, 2013) and beliefs on students' success (Burrichter, 2006) clearly impact pupils. Dell'Angelo (2010) shows when teachers perceive a high degree of obstacles to student learning, then, in fact, students' achievement level is lower. Conversely, when teachers perceive a lower degree of obstacles to student learning, then, students have higher achievement even when poverty levels are high.

Teacher's understanding of student perceptions, favourable relationships and better classroom dynamics improve attainment of lower SES pupils (Archambault, Janosz, & Chouinard, 2012; Whitehead, 2007). Schools giving more instructional time to reading and math have had a positive effect on high poverty students' scores (Chatterji, 2005). Teacher quality in high poverty school settings remains an important policy target for reform and improvement (Hogrebe & Tate, 2010). Teacher led classroom management and student behaviour positively correlates with student achievement (Marsden, 2006; southern Californian elementary school district). There is some evidence that teacher effects are more pronounced for maths attainment in high minority schools (Konstantopoulos & Chung, 2011). Teacher support acts as moderator for lower SES pupils and may even help change the negative trajectory found between poverty and academic achievement (Casper, 2013; Little-Harrison, 2012; Liu & Wang, 2008). A dedicated teacher cadre with high level of self-efficacy, cultural competency and those who can identify with the students either due to similar ethnicity, language, upbringing or SES, poverty or hardships help to make learning environment congenial (Freitas, 2013). High poverty schools with such teachers are high achieving schools.

4.4. Encouraging parental involvement

Parental involvement in their child's studies, particularly in terms of academic socialisation improves academic achievement and impacts the overall health and cumulative well-being of lower SES pupils (Westerlund et al., 2013). Educating parents and providing them with strategies to promote academic achievement increases achievement of high poverty kids. This has the long-term potential of changing the generational poverty cycle (Boggess, 2009) Parental support acts as a buffer between SES and academic achievement (Little-Harrison, 2012; Liu & Wang, 2008). Similarly, the under representation of minority female students has been shown to be positively impacted by support from family. Student decisions of continuing with STEM majors (Parker, 2013) is one such example. These results are important as they suggest how verbal persuasion and parental support can beat the odds through encouragement (Dowey, 2013).

4.5. Early intervention

Children with high parental expectations for education and maternal years of education are better able to benefit from typical teacher facilitated opportunities in learning basic mathematics skills improving their readiness to learn in kindergarten and beyond (Wang, Shen, & Byrnes, 2013). Children from deprived families are thus at an increased risk for early and prolonged academic and social difficulties. An effective intervention suggested for these children is attending pre-kindergarten programmes (Tucker-Drob, 2012). Children who receive lower levels of cognitive and language stimulation at home, belong to families receiving government assistance, have unemployed parents and less than a high school maternal education level have lower cognitive skill scores at the age of three (Ayoub et al., 2009). As discussed earlier when enrolled in (EHS) these children had higher cognitive skill scores at three years of age than their peers who were not in EHS. Formal childcare could thus offer a preventive means of attenuating deprivation effects on children's early academic trajectory (Geoffroy et al., 2010).

Verdugo (2011) shows by year 12 a large percentage of students leave school without graduating in the US. These findings are further supported by Vaz et al. (2014). The longitudinal study shows transition to secondary schools impacts AC of several groups of pupils. An early intervention is thus definitely required to extend support to disadvantaged pupils as is also supported by the multilevel cohort analysis of Singh (2012) which found a significant and dominant effect of academic performance in grade 3 on maths performance at 5th, 8th and 10th grades of native Hawaiian students.

4.6. Coordinated school health and breakfast programmes

Conducting a stepwise regression analysis on data from 50 states, Vinciullo and Bradley (2009) shows students in states promoting students' health demonstrated higher academic scores and higher rates of high school completion. High-stakes achievement testing suggests executive functions account for variance in maths attainment between children from poor urban environments and their elite peers (Waber et al., 2006). Efforts to improve children's academic achievement thus need to consider developmental factors and pupil health in addition to curriculum.

Basch (2011) explored the causal pathways between disparities of breakfast consumption among school-aged urban minority youth and their adverse academic achievement. On any given day a substantial proportion of American youth reported skipping breakfast. Neuroscience research has identified the processes by which dietary behaviour influences neuronal activity and synaptic plasticity, both of which influence cognitive functions. Participation in School Breakfast Programs has also been associated with reduced absenteeism. Universal School Breakfast Programs and allowing youth to eat breakfast in the school cafeteria are some approaches known to increase participation. Developed countries already offer reduced price lunches (US) and free school meals (UK). The added costs of breakfast program for disadvantaged pupils to the governments need to be investigated, while all evidence presented here supports benefits.

4.7. De-tracking and implementation of focused research-based instruction materials

A combination of research-based instructional materials from the University of Chicago School Mathematics Project with a multi-tiered teacher support system of sustained professional development and in-class coaching led to the evolution of Talent Development (TD) Middle School Model's mathematics programme. The main objective of the programme was to develop comprehensive and sustainable mathematics education reforms in high poverty middle schools (Balfanz, Mac Iver, & Byrnes, 2006). Outcome evaluation on various measures of achievement found TD students outperformed students from control schools on multiple measures of achievement with an effect size of 0.24, by the end of middle school. Similar programmes with the mission of improving the academic achievement of students who are often in the middle or average range and who are typically minorities and are economically disadvantaged have been shown to bring about significant improvement in mathematical achievement (Peak, 2011).

Ineffectiveness and inequities of ability grouping has long been debated. Burris, Wiley, Welner, and Murphy (2008) conducted a longitudinal study at a diverse sub-urban American high school in order to examine the long-term effects on the achievement of students. All students were given accelerated mathematics in a de-tracked middle school as well as ninth-grade "high-track" curriculum in all subjects in heterogeneously grouped classes. The quasi-experimental study analysed a pre- and post-reform success in the earning of the New York State Regents diploma and the diploma of the International Baccalaureate of the cohort. Binary logistic regression analysis showed a post-reform increase in the probability of students earning diplomas (Table 1).

The programme helped increase enrolment in International Baccalaureate classes and the average scores remained higher. The authors conclude that if a de-tracking reform includes high expectations for all students, sufficient resources and a commitment to the belief that students can achieve when they have access to enriched curriculum, it can be an effective strategy to help students reach high learning standards (Burris et al., 2008).

Table 1. Impact of reform on diploma attainment summarised from Burris et al. (2008)

Pupil identifier	Probability of diploma attainment
De-tracked cohort	70% greater chances
White/Asian students	3-fold increase
FSM eligible-African-American/Latinos	5-fold increase
FSM ineligible-African-Americans/Latinos	26-fold increase

Daw (2012) suggests increase in the amount of homework may increase the socio-economic achievement gap in maths and science in secondary school. It can be anticipated that the child may not have enough support at home. This further supports the use of focused instructional materials in school.

4.8. Checking aggression and violence in school

Criminal justice, aggression and violence are now recognised as hindrances to learning and teaching. They form an important focus of the education and public health systems. Implementing evidence-based school policies and programmes to reduce aggression and violence must be a high priority to help close the achievement gap (Basch, 2011). Evidence suggests emotional intelligence plays a significant role in predicting academic achievement for all students but more specifically for at-risk students (Nelson, 2009). Perhaps higher the emotional intelligence of a child at-risk the more sensitive he is and this can often serve as a protective cover against negative behaviour. The author argues using instructional strategies that develop emotional intelligence could help alleviate attainment gap for at-risk students.

4.9. Group counselling approach

Bruce, Getch, and Ziomek-Daigle (2009) evaluated the impact of a group counselling intervention on African-American students' achievement rates during the spring administration of high-stakes testing at a rural high school in Georgia. All participants had a pass score on Maths section of the Georgia High School Graduation Tests (GHSGT). Additionally, the achievement gap between African-American students and White students on the Enhanced Math narrowed during the 2007–2008 testing period, with 63.2% of African-American students achieving pass rates as compared to 70.5% of White students. The pass rate increased from the 38.7% pass rate among African-American students from the previous school year, indicating that the intervention was successful in improving pass rates on high-stakes testing. The study offers evidence base for professional school counsellors for utilizing the practice of group counselling to promote achievement among underachieving student subgroups (Bruce et al., 2009). Similarly, Pearson (2014) analysing factors that contribute to the success of minority students in maths, using a large longitudinal data-set shows school size and academic emphasis on a school level are important predictors of success.

4.10. Extracurricular activities

Kelepolo (2012) using a sample of $N = 654$ participants, 1107 non-participants shows the positive impact of participation in school sponsored extra-curricular activities on academic success. The outcome measure for the study- performance in Utah's criterion-referenced tests, include assessment of maths and science. Successful high achieving high poverty schools have been shown to take steps to involve all students in some kind of extracurricular programme. These activities were found to be an incentive that gave students the initiative to remain in school rather than dropping out (Killgo, 2012). Also perhaps spending an extra hour on training beyond school teaching with a responsible adult instils positive values in the young learner thereby raising attainment.

5. Limitations of the study

The review was initiated as a part of a major PhD project evaluating the impact of STEM interventions in improving attainment, increasing and widening participation (Banerjee, 2015). Any piece of primary research ought to be preceded by a systematic review. The key advantage of a systematic

review over the traditional narrative review is its ability to identify all the available evidence in a systematic and replicable manner. Thus rather than a narrative literature review a systematic approach was taken. Systematic reviews are normally conducted by teams this divides the work load, increases reliability and reduces researcher's bias. However, given the context of the review it was not possible for the author to screen millions of papers single-handedly in the given time frame. A conscious choice of not considering any master's thesis was thus made. This is because Master's theses were huge in number (in thousands), most often short superficial reports. Some of these for example were essays on underachievement and not real investigations. It was difficult to manage reading all of them thus these were excluded in favour of PhD theses which were also in thousands but gave a relatively detailed robust research report. This is one of the known limitations of the review and it is possible some significant information might have been lost. Also though the syntax was tested and framed with advice from experts as is true of all systematic reviews not always every relevant paper gets picked up. Yet given these conditions this systematic review is the best it could have possibly been as a 10% sample has been double screened and quality assessed for the paper.

Also as the main research project was focused on England, this systematic review identified papers which were relevant to the UK context. Hence the search terms were US/UK centric for example deprivation measures and the policies referred to in this paper. Only papers published in English language were considered due to author's limitations. Studies retrieved from systematic searching and screening offering insights to the main research question were mostly correlational in research design. Some causal studies known to the author were added. Although these were included through expert knowledge of the literature and not through the systematic searching (and therefore could be a biased sample of such studies), nevertheless it was important to include these because these were robust studies addressing the research question.

6. Conclusion

While their journey on educational trajectories and life in general is harder compared to those from privileged backgrounds there are students who despite qualifying for several measures of disadvantage embody resiliency. Equally important are the measures adopted by high attaining schools with a high percentage of disadvantaged pupils. With educational policies like widening participation, Education for All and No child left behind there is hope that all children will reach their full potential, both academically and in other lifelong pursuits. The systematic review has identified a range of factors linked to underachievement of disadvantaged pupils in school science and maths. STEM skills are considered valuable for economic progress and are highly valued in the labour market. It is certainly important to have an evidence base from research reports to understand the factors that hinder attainment of disadvantaged pupils in these subjects. The review has summarised literature that examines current practices and then offers practical solutions for the arduous task of improving educational attainment of these pupils in science and maths in schools. This is crucial because a good grade in science and maths is a pre-requisite for admission to most STEM courses. Lower attainment in these subjects leaves these children ineligible for entry into high-esteem STEM programmes.

Using PISA data OECD (2016) has identified major individual, family, regional and school level factors associated with differential attainment in maths and science. This paper shows the snowballing effect of a number of familial (teen mother, low maternal education), social (homelessness, maltreatment), school-related and biological (inadequate prenatal care, pre-term, low birth weight, lead exposure, malnourishment) risk experiences on both academic and behavioural outcomes (Rouse, Fantuzzo, & LeBoeuf, 2011). This means children who qualify for one of the deprivation measures normally do qualify for several others, making it harder for a child to cope up. For example, a family managing with very less income does live in a high poverty neighbourhood exposing children to high risk behaviours. Such parents very rarely have the time, resources or means to get involved in the education of their children. Perhaps the only focus then becomes to earn money for survival with education not providing any short-term benefits for the family such as meeting needs of day-to-day life and perhaps thus takes a back seat. Young people from such families thus frequently dropout of

education or start working at lower level jobs. Implications for policy and practice identified in review are discussed. It is crucial to address these concerns first to support educational attainment of these children to be able to reduce the STEM achievement and participation gap in future.

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This systematic review was initiated as part of my PhD thesis. The project evaluated the impact of STEM enrichment and enhancement activities on increasing and widening participation over the last decade in UK. Rather than a narrative literature review this systematic review was conducted to understand the factors which are linked to underachievement of disadvantaged pupils in STEM subjects. I am grateful to Professor Carole Torgerson my PhD supervisor for the methodological expertise.

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